DONALDSON, RALPH THAD. A Response-Initiated Differential Reinforcement of Low Rates Schedule of Reinforcement. (1972) Directed by: Dr. Richard L. Shull. Pp. 38.

The purpose of the present research was to study the effects of timing and motivational variables on a two-response DRL schedule. The primary question was whether or not timing behavior and the response-strengthening effects of reinforcement are confounded in DRL performance.

The subjects were albino rats maintained at 80% of their free-feeding body weights, and the reinforcing event was dipper presentation of a sucrose solution. A procedure was used in which two responses were required for the reinforcing event to occur. The minimum latency contingency was imposed only on the latency of the second response.

When the DRL value was varied the timing interval matched the DRL requirement more closely than in one-response DRL performance. When the subjects were pre-fed prior to the sessions to decrease the severity of deprivation, the frequency of timing behavior decreased but the accuracy of the timing intervals remained unaffected. In extinction the accuracy of timing was maintained even as the frequency of the timing behavior reached zero.

It was concluded that the strengthening effects of reinforcement presented in time are indeed confounded with the effects of reinforcement differentially presented on DRL schedules. Additionally, it was concluded that the

two-response DRL procedure allowed for these different kinds of variables to differentially affect latencies independently sensitive to them.

A RESPONSE-INITIATED DIFFERENTIAL REINFORCEMENT OF LOW RATES SCHEDULE OF REINFORCEMENT

by

Ralph Thad Donaldson

A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Greensboro
1972

Approved by

Thesis Adviser

This thesis has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

Thesis Adviser Robert L. Shurtleff

Oral Examination Committee Members Aaron J. Brownstein

Elbert H. Evans

4/14/1972
Date of Examination

ACKNOWLEDGMENT

The author wishes to express sincere appreciation to the members of his thesis committee who were of invaluable assistance throughout the performance of the research and preparation of this manuscript.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

On a differential reinforcement of low rates (DRL) schedule, reinforcement depends upon minimum temporal spacing of responses. For the reinforcing event to occur, a particular response must follow the previous response or reinforcing event by at least a specified interval. If a response occurs before the minimum interval has elapsed, the reinforcer is not presented and the minimum interval contingency is reset. The interval between responses is called the interresponse time (IRT). In traditional DRL research the interval between the end of the reinforcing event and the following response, the post-reinforcement pause, is recorded and analyzed as an IRT and reinforced according to the same conditions as the IRT. In the terminology of Ferster and Skinner (1957), the schedule described is called crf drl, that is, continuous reinforcement of IRTs which exceed the minimum interval. In this paper, except where specified otherwise, DRL will be used to refer to crf drl.

Skinner's (1938) original use of the differential reinforcement of low rates was, however, somewhat different. Skinner's purpose was to show that response rate on reinforcement schedules was to some extent determined by the conditions prevailing at the moment of reinforcement.

After shifting from a fixed-ratio schedule, which usually maintains high response rates, to a variable-interval schedule, which usually maintains intermediate rates of responding, he observed maintainence of response rates characteristic of the fixed-ratio schedule. The rate of reinforcement of the variable-interval schedule was programmed to equal that of the fixed-ratio schedule. Skinner reasoned that the high response rate carried over from the fixed-ratio schedule was spuriously correlated with the reinforcing events programmed by the variable-interval schedule. An added requirement that the reinforcing event would follow only IRTs exceeding a certain value altered the conditions at the moment of reinforcement without affecting the overall reinforcement rate. The results showed immediate and lasting decreases in response rates. A final control reinstated the fixed-ratio contingency with no DRL requirement and showed the rate to increase to the former high level. Thus, with the reinforcement rate held constant, changing the characteristics of the terminal IRT produced significant changes in overall response rates. Additional experiments using DRL to pace responding on intermittent reinforcement schedules have been reported by Anger (1956); Farmer and Schoenfeld (1964); and Elsmore (1971).

On DRL schedules of the crf drl type, IRT length increases as a linear function of increasing DRL requirement. However, IRT length may be significantly shorter than the

programmed DRL requirement (Wilson and Keller, 1953). DRL values greater than twenty or thirty seconds may result in little or no schedule control (Staddon, 1965). Frequency distributions of IRTs normally have a mode which is equal to or near the minimum reinforced IRT. An additional mode usually appears at the shortest IRT value. This preponderance of short IRTs is called "bursting" (Sidman, 1956). That bursting even occurs seems inappropriate in view of the reinforcement contingency requiring IRTs much longer than the ones in bursts.

Motivational variables such as deprivation, satiation, and amount of reinforcement affect IRT length in DRL schedules but not in an unequivocal manner as will be indicated by the following references. Increased deprivation (Conrad, Sidman and Herrnstein, 1958) resulted in decreased IRT lengths, but only at less severe levels of deprivation. At more severe levels of deprivation the function was essentially flat. Progressive satiation (Conrad, Sidman and Herrnstein, 1958) curves were essentially flat until, after many hours, the IRT length began to increase as a function of increasing satiation. IRT length decreased as number of food pellets per reinforcing event was increased (Beer and Trumble, 1965). The conditioned suppression procedure (Estes and Skinner, 1941) has been shown to affect DRL performance in a paradoxical way (Finocchio, 1963). At lower shock intensities the procedure actually resulted in

increased responding during the warning stimulus. Only at increased shock intensities did the conditioned suppression procedure result in suppression.

Reynolds (1964b) reinforced pigeons' keypecking on a DRL schedule requiring an IRT exceeding 20 seconds. A pattern of performance developed in which the conditional probability of very short IRTs was quite low while the conditional probability of IRTs longer than five seconds was higher. Conditional probability curves for IRTs longer than five seconds were essentially flat. This indicated random occurrence of IRTs longer than five seconds with no evidence of control by time since the last response. Satiation, as indicated by increased body weights, resulted in very low conditional probability at very short IRTs with increasing conditional probability for IRTs up to 20 seconds long. As reflected in the conditional probability distributions, the DRL schedule appeared to exert greater temporal control over IRTs during satiation. Very similar gradually increasing conditional probability curves occurred when reinforcement was completely removed from the situation. Conditional probability distributions which peaked at or near the IRT matching the DRL value appeared to indicate greater DRL schedule control during satiation and extinction. This is more likely a result of decreased response rate which is the usual effect of satiation and extinction. Reconditioning following extinction (Reynolds, 1964a) was

both rapid and precise. On the first day of reconditioning, the conditional probability distributions looked very much like those of the last day of baseline performance. Reynolds claimed that this indicated that the timing behavior iteslf was unaffected by the removal of reinforcement. The timing behavior just occurred less and less often.

Some of the ambiguities which arise in DRL performance under the influence of motivational variables may be better understood by analyzing response probability in terms of variables affecting response strength and variables affecting temporal control. Reynolds (1964b) has stated that two functions of the reinforcing event may be separable in the DRL schedule, "...the one to maintain responding at an appropriate rate, the other to bring responding under the discriminative control of additional stimuli in whose presence it is reinforced (p. 421)." Reinforcement serves to maintain a rate of responding commensurate with the rate of reinforcement (Skinner, 1938; Catania and Reynolds, 1968). This will be referred to as the strengthening effect of reinforcement. On the DRL schedule response emission can come under the control of time since the previous response or reinforcing event. This effect of the DRL contingency will be referred to as timing.

To explore the possibility that these two kinds of variables are confounded in DRL performance, a procedure was devised to distinguish the strengthening effects from the

differential timing effects exerted by the schedule (Mechner and Guevrekian, 1962). Two responses were required for the reinforcing event to occur. A response on lever B, if it followed a response on lever A by at least the minimum required interval, was followed by the reinforcing event. If an interval shorter than the required one separated the A and B responses, the reinforcer was not presented and another A-B sequence had to be initiated. The latency of response A had no minimum temporal requirements at all. Logically then, this latency was thought to be free of the timing aspect of the schedule while still being very much a function of strengthening variables. The latency of response B had both timing and strengthening constraints. To be followed by the reinforcer, the response had to have a latency equal to or exceeding the minimum fixed interval required by the schedule. Both latencies were equally a function of strengthening variables. Differences in the two latencies, then, were a function of factors other than strengthening variables.

Mechner and Guevrekian (1962) investigated the effects of deprivation on DRL behavior using the two-response procedure. The results showed that the mean A-B interval did not vary across all levels of deprivation. The post-reinforcement pause, however, was shown to decrease as deprivation level was increased. These results were superficially quite contradictory to those of Conrad, Sidman and

Herrnstein (1958) which showed IRT length to be very much a function of deprivation at low deprivation levels. When the post-reinforcement pauses and A-B intervals were combined, however, the results were quite compatible with those of Conrad, Sidman and Herrnstein. From the Mechner and Guevrekian experiment it became clear that the two-response DRL procedure allowed at least a partial separation of strengthening and timing variables in the DRL situation.

Migler and Brady (1964) reported an experiment which will give further background on the two-response DRL and may help shed some light on the questions arising from Finocchio's (1963) data referred to above. They imposed the conditioned suppression procedure upon the baseline of a two-response DRL. The results indicated that the warning stimulus had no effect upon the latency of the B-response, given that the A-response had already occurred. If the A-response had not been made, its probability, as reflected by greatly increased latency, was markedly decreased by the warning stimulus. The A-B time, which was not affected by the warning stimulus, was the latency upon which there were timing or fixed minimum interval constraints. The latency of the A-response, with no timing requirements and perhaps a function of strengthening variables alone, was greatly increased during the warning stimulus. The suppressive effect of the warning stimulus affected only the latency upon which there were no timing constraints.

Apparently the timing constraints placed on the latency of the B-response in this context resulted in an insensitivity of this latency to the independent variables manipulated. The present research also sought to separate timing variables from other variables in the DRL situation. The strengthening and timing effects in the DRL were studied in particular.

The present research employed a response-initiated differential reinforcement of low rates schedule. This consisted of a two-response DRL in an apparatus which contained only one manipulandum. The two responses were separated by exteroceptive stimulus changes contingent upon the occurrence of the responses. One purpose of the present research was to determine the functional equivalence of the one-lever, two-response procedure to the two-lever, two-response procedure of Mechner and Guevrekian (1962) and Migler and Brady (1964).

The research to be reported was divided into three experiments. The primary purpose of the first experiment was to examine the effects of increasing DRL value on a two-response DRL. The Mechner and Guevrekian (1962) and Migler and Brady (1964) studies used steady-state behavior at a DRL value of five seconds only. Results by Wilson and Keller (1953) using a one-response DRL showed that the median IRT length increased linearly with increases in DRL value. The median IRT consistently underestimated the

required minimum interval, though. The data by Mechner and Guevrekian, and Migler and Brady with a two-response DRL suggest that this might have been the result of two kinds of variables combined. A parametric treatment of a response-initiated DRL schedule might yield A-B IRTs more closely approximating the required intervals. B-A times and post-reinforcement pauses should occur at values shorter than the minimum reinforced interval.

The purpose of the second experiment was to investigate the effects of pre-feeding on the response-initiated DRL. Pre-feeding with a sucrose solution reinforcer allows an immediate change in deprivation level which is easily specifiable and does not affect day-to-day body weights seriously. In view of the data presented by Mechner and Guevrekian (1962) and Migler and Brady (1964) the change in the motivational variable should affect only the post-reinforcement pauses and B-A intervals. The A-B intervals, or timing intervals, should not vary as a function of deprivation changes.

The purpose of the final experiment was to determine the effect of removal of reinforcement on the response-initiated DRL. In view of the data and discussion by Reynolds (1964a), the timing latency required for reinforcement should not change in mean length. The frequency of occurrence of the sequence should decrease sharply. Technically, the A-B interval should remain unchanged while

the B-A interval should increase and approach infinity as the response rate approaches zero.

METHOD

Subjects

The subjects were four male albino rats obtained from the Holtzman Company. They were maintained at 80% of their free-feeding body weights throughout the experiments. The rats were six months of age at the beginning of the present research and had a two-month history of responding on fixed-ratio, fixed-interval, and differential reinforcement of low rate schedules of reinforcement.

Apparatus

A standard operant conditioning test cage (Lehigh Valley Electronics #1316) enclosed in a light and sound attenuating chamber (Lehigh Valley Electronics #1316c) served as the experimental chamber. The chamber was equipped with a blower which provided ventilation and noise masking. The test cage contained one lever and one stimulus light. A houselight providing general illumination was located just outside the glass-enclosed test cage. Electromechanical equipment programmed stimulus changes and reinforcing events, and recorded performance. Reinforcing events consisted of 3-second dipper presentations of 0.1 milliliter of 16% sucrose solution, by weight.

Procedure

The basic schedule arranged that the first response of a pair turned on the stimulus light in the chamber and the second response of the pair turned off the light. If the time between the initiating response and the terminating response equaled or exceeded a minimum required interval, the reinforcer was produced by the terminating response. If the time between the initiating response and the terminating response was less than the required minimum interval, the light was turned off and the reinforcer was not produced. Following a terminating response, whether or not the reinforcer was presented, a response was necessary to turn the light on and re-initiate the DRL interval. The schedule was designated a response-initiated differential reinforcement of low rate schedule. Each experimental session continued until 51 reinforcing events had occurred.

Experiment I: Acquisition

An ascending series of DRL values, 5, 10, and 20 seconds, was presented. Each DRL value was in effect for 30 daily sessions.

Experiment II: Pre-feeding

The effects of pre-feeding were examined using the DRL 20 seconds baseline established in Experiment I. Pre-feeding consisted of placing a glass bowl containing 16% sucrose solution in the chamber with the subject for one

hour prior to the beginning of each daily session. The order of the conditions was as follows: A no pre-feeding baseline (30 sessions in addition to the 30 sessions reported in Experiment I), 20 ml pre-feeding (5 sessions), return to baseline (5 sessions), 40 ml pre-feeding (5 sessions), and return to baseline (5 sessions).

Experiment III: Extinction

In the extinction experiment all schedule and apparatus components operated in the normal way, the exception being that when presented, the dipper contained no sucrose solution. Extinction sessions continued until 51 reinforcing events would normally have been presented or until one hour had elapsed, whichever occurred first. The extinction experiment continued for 15 daily sessions. Baseline conditions were determined before reinforcement was removed and redetermined after reinforcement was reinstated.

RESULTS

The data to be reported were analyzed in terms of the mean latencies of the two responses. The time between the end of a reinforcing event, or a timing interval too short to be reinforced, and an initiating response, that is, the latency of the initiating response, was called Out Time. The Out Time is analogous to the B-A times in the Mechner and Guevrekian (1962) experiment. The time between the initiating response and the terminating response, that is, the latency of the terminating response, was called In Time. In Time is analogous to the A-B times in Mechner and Guevrekian's terminology. Total In Time, summed over a complete session, was divided by one-half the responses occurring in the session to give the mean In Time for that session. Mean Out Time was calculated in an analogous way. Out Times following reinforcing events, post-reinforcement pauses, were recorded separately from Out Times following In Times too short to be followed by the reinforcing event. In the present analysis the term Out Time refers to the combination of these two kinds of intervals.

Experiment I: Acquisition

Figure 1 shows the mean In Time and mean Out Time of the last five sessions of each condition in Experiment I.

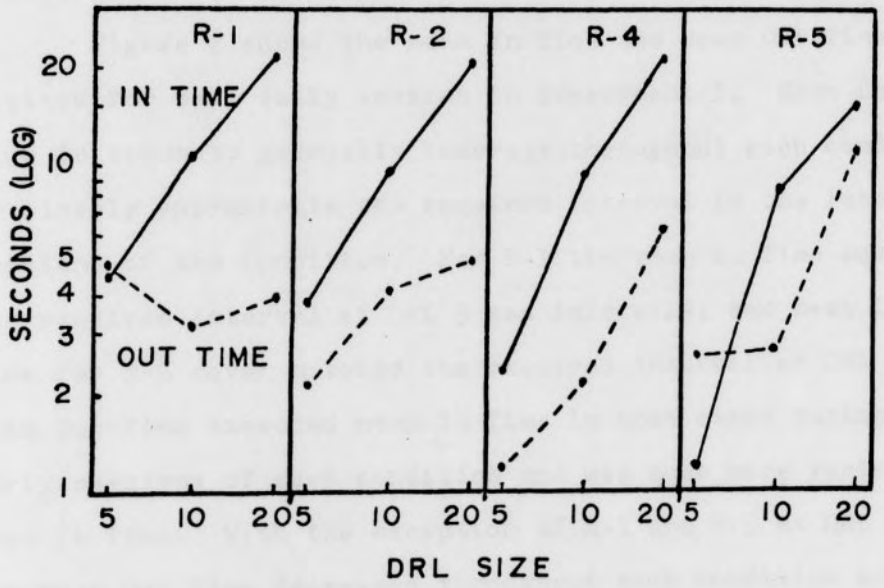

Figure 1. Mean In Time and Mean Out Time as a Function of DRL Size--Means of the Last Five Sessions.

Mean In Time increased as a function of increasing DRL requirement and approximated the required minimum interval. Mean Out Time also increased as the minimum required interval was increased but, except for R-1 and R-5 at DRL 5 sec, was always less than mean In Time.

Figure 2 shows the mean In Time and mean Out Time plotted for each daily session in Experiment I. Mean In Time is shown to gradually increase throughout each condition to closely approximate the required interval in the later sessions of the condition. For R-1 the mean In Time equaled the required interval at DRL 5 sec initially, and mean In Time for R-5 never matched the required interval at DRL 5 sec. Mean Out Time exceeded mean In Time in most cases during the early sessions of each condition and was much more variable than In Time. With the exception of R-1 and R-5 at DRL 5 sec, the mean Out Time decreased throughout each condition and by the end of a condition was considerably less than mean In Time.

Experiment II: Pre-feeding

Figure 3 shows the mean In Time and mean Out Time for the last five days of the baseline condition and all successive sessions in Experiment II. Frame A of Figure 3 shows baseline performance on the DRL 20 sec schedule. In Time, the latency of the terminating response, matched the minimum interval required by the schedule. Out Time, the latency

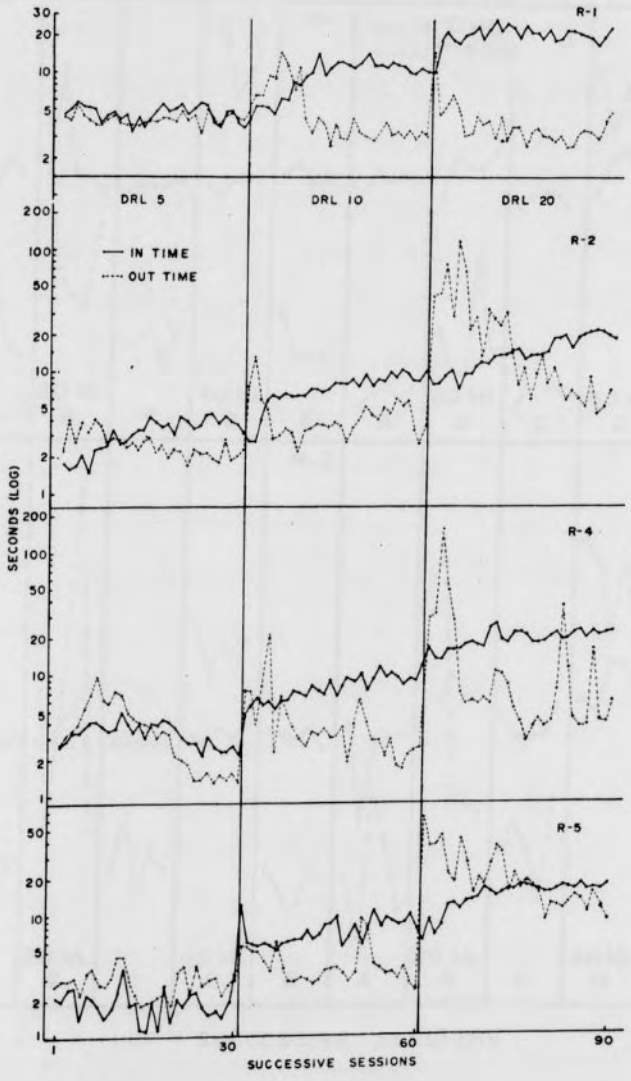

Figure 2. Mean In Time and Mean Out Time as a Function of DRL Size--Successive Sessions.

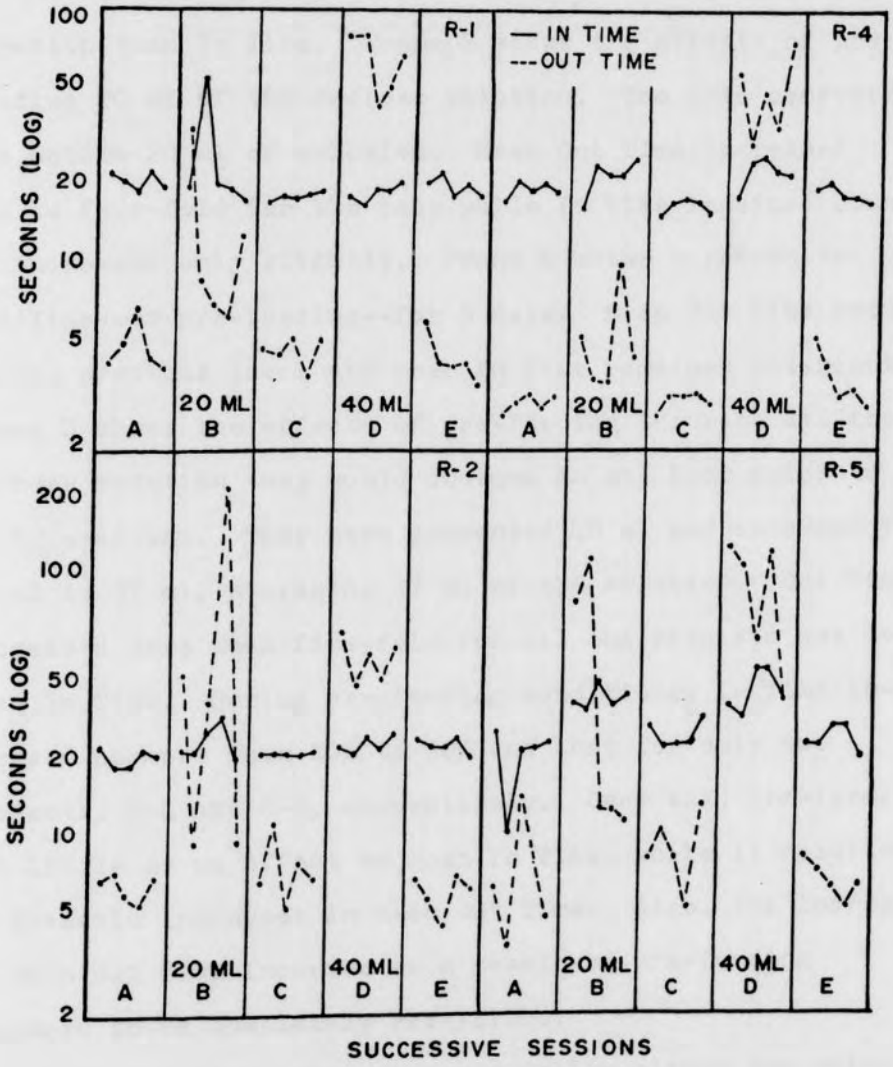

Figure 3. Mean In Time and Mean Out Time as a Function of Pre-feeding.

of the initiating response, was constant at a shorter duration than In Time. Frame B shows the effects of pre-feeding 20 ml of 16% sucrose solution. The rats consumed the entire 20 ml of solution. Mean Out Time increased two to four-fold for the rats while In Time remained constant or increased only slightly. Frame C shows a return to baseline--no pre-feeding--for 5 days. Mean Out Time returned to its previous level and mean In Time remained invariant. Frame D shows the effects of pre-feeding the rats all the 16% sucrose solution they would consume in one hour prior to the daily sessions. They were presented 40 ml and consumed from 19 ml to 37 ml, averaging 27 ml of the solution. Out Time increased more than five-fold for all the rats and was longer than In Time. During pre-feeding conditions, In Time increased no more than 10% to 30% and that for only two subjects, R-4 and R-5, respectively. Over all, pre-feeding had little or no effect on mean In Time, while it resulted in dramatic increases in mean Out Time. Also, the increases in mean Out Time incurred as a result of pre-feeding appeared to be completely reversible.

An Out Time interval could follow either the reinforcing event, the post-reinforcement pause, or an In Time too short to be reinforced, the post-error pause. Figure 4 was constructed to determine if there was any systematic difference between Out Times following the reinforcing events and Out Times following In Times too short to be reinforced.

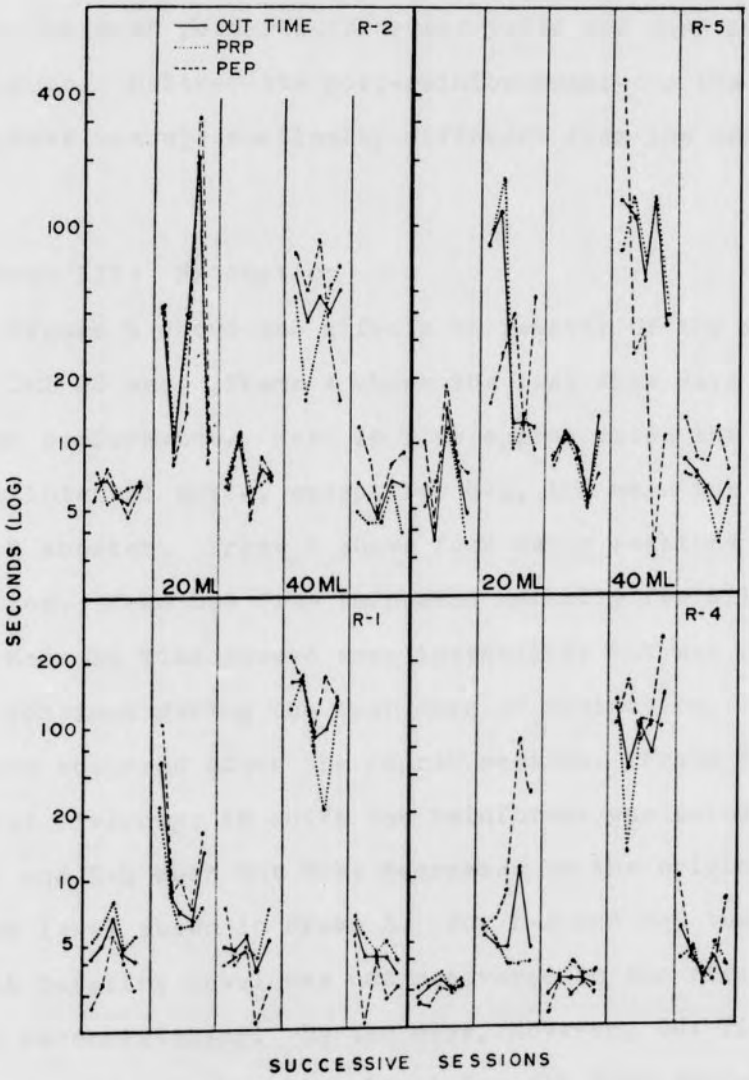

Figure 4. Mean Out Time Compared with Mean Post-Reinforcement Pause and Mean Post-Error Pause.

Figure 4 shows mean Out Time, just as in Figure 3, compared to both the mean post-reinforcement pause and mean post-error pause. Neither the post-reinforcement nor the post-error pause was systematically different from the mean Out Time.

Experiment III: Extinction

Figure 5 shows the effects of removal of the reinforcer on DRL 20 sec. Frame A shows the last five days of baseline performance. Mean In Time approximated the required minimum interval while, except for R-5, the mean Out Time was much shorter. Frame B shows four daily sessions of extinction. Mean Out Time increased markedly for all four rats. Mean In Time showed some instability but was essentially constant during the four days of extinction. No responses occurred after the fourth session. Frame C shows the first five days in which the reinforcer was reinstated. For R-1 and R-4 mean Out Time decreased to the original baseline level shown in Frame A. For R-2 and R-5 the original baseline level was not recovered in the first five days of reconditioning. By ten days, however, Out Time had returned to the baseline level for all four subjects.

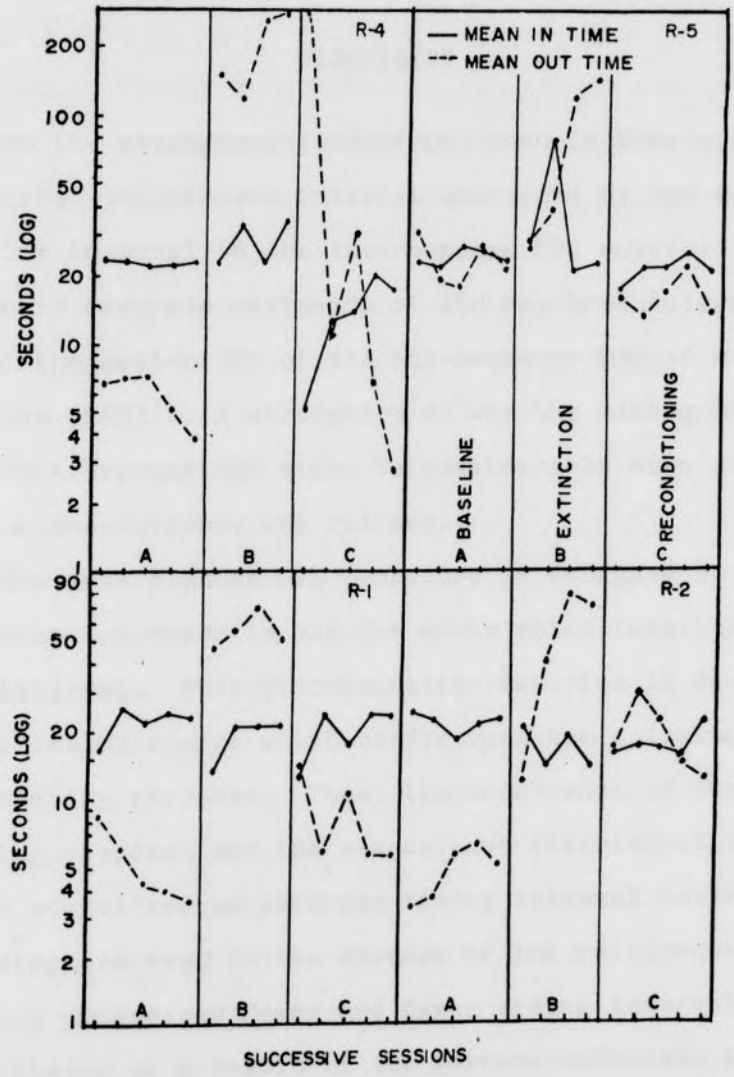

Figure 5. Mean In Time and Mean Out Time as a Function of the Removal of the Reinforcer.

DISCUSSION

On the response-initiated DRL mean In Time closely approximated the minimum interval specified by the schedule. The timing interval in the two-response DRL appeared to be a much more accurate estimator of the required interval than did the median IRT of the one-response DRL of Wilson and Keller (1953). A discussion of why the timing interval in the two-response DRL might be considerably more accurate than in a one-response DRL follows.

The two-response DRL procedure is designed so that the reinforcing event is not the event which occasions the timing interval. This discriminative function is served by the stimulus change which occurs upon the emission of the initiating response. Thus, the occurrence of the initiating response and the concomitant discriminative stimulus occasioned an accurate timing interval during pre-feeding and even in the absence of the reinforcer. As extinction progressed fewer and fewer timing intervals were initiated as a result of the extreme reduction in overall response rate. To the very cessation of all responding, whenever an initiating response occurred, after however long an Out Time, the ensueing In Time closely approximated the required interval. Staddon (1969) has demonstrated that informative feedback may not be of great

assistance in performance on DRL schedules. However, Staddon's informative stimuli were quite complex and since the presence of the discriminative stimuli in the two-response DRL is another difference from the one-response DRL, this feedback warrants consideration. Although the frequency of occurrence of timing intervals was greatly decreased during extinction, the accuracy of the timing interval in estimating the DRL value was unaffected. Only with a discriminable timing interval could this maintainence of timing accuracy have been detected against the general decrease in response rate.

After each In Time which was too short to be followed by the reinforcing event, an Out Time immediately occurred. Out Times were never immediately followed by the reinforcing event. Therefore, Out Time can be considered as time out from positive reinforcement. If it served as a punishing stimulus, the time out from positive reinforcement would be expected to reduce the frequency of errors; thereby increasing accuracy. Time out from positive reinforcement has been shown to reduce errors in a matching-to-sample task (Ferster and Appel, 1961; Zimmerman and Ferster, 1963). The duration of the Out Time, however, was not controlled by the experimenter as is usually the case in punishment procedures. Additionally, Out Times followed reinforcing events as well as In Times too short to be reinforced. These two restrictions may have attenuated the effects of

Out Time as a punishing stimulus. However, time out from positive reinforcement must still be considered as a factor in the control of performance on a two-response DRL.

Experiments II and III showed that In Time and Out Time were independent with respect to deprivation and removal of reinforcement. In Time remained unchanged while the effects of these variables were shown in changes in Out Time. In Experiment I however, there appeared to be a correlation between In Time and Out Time. Since Out Time had no programmed temporal restraints, the fact that it increased as a function of increasing DRL value requires further discussion. As the DRL value was increased, the maximum possible reinforcement rate was decreased. As previously noted (Catania and Reynolds, 1968), reinforcement maintains a rate of responding commensurate with the rate of reinforcement. As the DRL was increased the rate of reinforcement was decreased, and therefore the rate of responding would normally have decreased, even if the DRL contingency itself had not required it. The increase in mean Out Time could be attributed to decreased reinforcement rate. The difference between the two latencies, however, cannot be explained by reinforcement rate.

The latency of the terminating response, In Time, has temporal constraints imposed on it, the minimum reinforced interval or DRL value. It is possible that adjacent latencies might be affected by the temporal

requirements on this latency. Response induction is the spread of reinforcement effects to responses other than the one directly reinforced (Catania, 1968). Thus the differential control imposed on the timing interval by the reinforcement contingencies might possibly influence the latencies of adjacent responses. Thus response induction could account for the increase in Out Time as the DRL value was increased. The temporal effects arising from response induction would not be expected to be as strong as those imposed directly by the differential reinforcement schedule. Therefore the principle of induction would also account for the difference in the two functions shown in Figure 1.

Since Out Time and the initiating response are never followed immediately by the reinforcing event, delay of reinforcement could possibly play a role in the two-response DRL situation. The delay of reinforcement of the initiating response is equal to the following In Time, given that the In Time exceeds the required minimum interval. Delayed reinforcement results in lower response rates (Skinner, 1938; Keller and Schoenfeld, 1950).than does immediate reinforcement. Thus, delayed reinforcement could account for the increase in Out Time as a function of increasing DRL value since increasing the DRL value increased the minimum reinforcement delay for the initiating response. The latency of this response would be expected to increase as the delay of reinforcement increased. If acting alone, the principle

of delayed reinforcement could account for the increase in mean Out Time as a function of increasing DRL value. Delay of reinforcement could also be responsible for a difference between In Time and Out Time, but the difference would be opposite to the one observed. That is, the delayed reinforcement principle would predict that Out Time, the latency more remote from the reinforcing event, would be greater than In Time, the latency immediately preceeding the reinforcing event.

Since both responses in the two-response DRL are maintained by the same rate of reinforcement, their difference in latency cannot be attributed to this factor. Since the principle of delayed reinforcement would predict differences opposite to those obtained in Experiment I, this principle, though quite useful for predicting the increasing functions, is of limited use in explaining the latency differences. Response induction, as well as reinforcement rate and delay changes, could account for the increase in Out Time. Response induction could also account for the difference in In Time and Out Time. Response induction in this case, however, is a by-product of the differential reinforcement contingencies placed on the timing interval. It seems to follow that the differential control observed in the response-initiated DRL performance is exerted by the timing constraints or DRL contingency on the In Time. The DRL contingency requires

that the In Time exceed a specified duration. This alone appears to account for the control observed.

Generally, abruptly increasing the value of the DRL resulted in a gradual increase in mean In Time until this latency closely matched the schedule requirement (see Figure 2). Increasing the DRL also resulted in increased variability in Out Time in the early sessions at the new DRL value. As the new condition progressed, mean Out Time generally decreased to reach a value much smaller than mean In Time. On a DRL schedule, as the DRL value is increased, reinforcement rate is automatically decreased, reinforcement delay is increased, and the rate of both responses decreases. Mean In Time gradually increased to meet the DRL contingency and the rate of reinforcement increased to a value more nearly approximating the programmed maximum. As the reinforcement rate increased the rate of responding increased and mean Out Time decreased. Thus the dissipation of the initial large and variable increases in Out Time concomitant with a gradual increase in mean In Time appears to be a function of an interaction between the differential shaping up of the timing interval and the consequent increase in reinforcement rate.

In contrast to the small effects in In Time, pre-feeding produced large increases in mean Out Time in Experiment II. The relative invariance of In Time suggests that deprivation level has little effect on timing accuracy.

Dinsmoor (1952) has also shown that deprivation severity has little effect upon accuracy in the performance of a discriminated operant. Deprivation level does influence the probability of initiating the timing component of the schedule. These data are consistent with those of Mechner and Guevrekian (1962) which showed that post-reinforcement pauses varied as a function of deprivation level, but the average IRT was unaffected on the two-response DRL. There are at least two possible interpretations of these data. Perhaps the temporal restrictions in the DRL segment override the effects of deprivation changes on response probability. The lack of temporal constraints in the pre-DRL segment might permit deprivation effects to exert relatively stronger control. Alternatively, the presence or absence of temporal constraints might be unimportant. Instead, behavior in components of chained schedules that are close to reinforcement may be less sensitive to deprivation changes than behavior in more remote components of chained schedules (Ferster and Skinner, 1957; Kelleher and Gollub, 1962). The response-initiated DRL can be considered a chained schedule (chain FR 1, DRL 20 sec).

An analysis of the two-response DRL in terms of response chaining presupposes that the presence of the light during the timing interval serves as a discriminative stimulus. This assumption was not tested in the present research. However, the alternative view, that the light

has acquired no discriminative properties, is implausible in view of the data that is presented. The difference between In Time and Out Time and the independence of these two latencies are strong evidence that the two kinds of latencies are discriminable. The increased accuracy of the timing performance, that is, the matching of In Time to the DRL requirement while Out Time stabilized at shorter values, is further evidence. Due to the indirect evidence and the argument above a two-response DRL procedure in which there is no exteroceptive stimulus change to separate the two kinds of latencies would not be expected to result in latency differences like those in Figure 1. An experiment to test this hypothesis directly would consist of a tandem control to see if the schedule operates as a chained schedule as discussed above.

Removal of the reinforcer in Experiment III resulted in dramatic response rate reduction. This reduction was a result of increased Out Time alone, since mean In Time did not change. This indicates that the control of the timing interval was unaffected by removal of the reinforcer. The frequency of occurrence of the timing interval was decreased, however. The re-introduction of the reinforcer into the situation resulted in an increase in the response rate to a point equal to the pre-extinction level. This was totally a function of decreased Out Time since In Time remained constant during this condition also. The rapidity and

accuracy of reconditioning of the timing behavior are very similar to results reported by Reynolds (1964a). The constancy of the In Time latency in the absence of the reinforcer lends additional support to Reynolds's statement that timing "...performance has not been lost during extinction, rather it lacks one of its conditions of occurrence, the reinforcer (p. 275)." Due to the response-initiated feature of the schedule used in the present research the timing behavior was not only observable but was also unaffected in extinction.

In Experiment I In Time and Out Time appeared to be correlated. However, this seems to be adequately accounted for by analyses in terms of reinforcement rate changes, reinforcement delay changes, and response induction. Experiments II and III indicated that In Time and Out Time were independent of each other; at least at the schedule parameters used and relative to the independent variables manipulated. This independence appeared to be a function of the presence of differential reinforcement contingencies on the In Time latency while there were no differential contingencies on Out Time.

Out Time has been discussed as being primarily a function of strengthening variables or reinforcement variables. An Out Time could follow an unreinforced In Time as well as a reinforcing event. It is possible that the occurrence or non-occurrence of the reinforcing event could

influence the length of Out Time. For example, reinforcement might lead to an increased Out Time due to an inhibitory function of the reinforcing event (Staddon and Innis, 1969). Likewise, non-reinforcement might result in a "frustration effect" characterized by decreased Out Time (Amsel, 1958; Staddon and Innis, 1969). These hypotheses would predict post-reinforcement pauses longer than the mean Out Times and post-error pauses shorter than the mean Out Times. The mean Out Time would only be a weighted mean of these two kinds of latencies and would be a poor predictor of either. The data presented in Figure 4 indicate that neither of these effects occurred in the two-response DRL studied. Out Times following an In Time too short to be reinforced and Out Times following a reinforcing event were essentially equal.

From the data presented, it appears that the present one-lever, two-response DRL procedure is functionally equivalent to the two-lever, two-response DRL procedure of Mechner and Guevrekian (1962). The discriminative stimulus separated the initiating and terminating responses as effectively as do two levers.

The present research has indicated that a two-response DRL procedure results in more accurate timing behavior than the one-response DRL. Motivational variables were shown to have no effect on the accuracy of the timing behavior. The frequency of the timing behavior, however, was shown to

vary as a function of the motivational variables manipulated. Even in extinction timing accuracy was unaffected. The latencies of the two responses in the two-response DRL procedure were shown to be relatively independent at a particular DRL value.

The present results support the initial contention that response strengthening and differential effects are confounded in DRL performance. Additionally, the two-response DRL procedure allows at least a partial partitioning of these two variables. The difference between one latency presumably under the control of strengthening variables alone and another latency under the control of both strengthening and differential reinforcement variables can logically be attributed to the differential contingencies defining the differential reinforcement of low rates schedule.

SUMMARY

The purpose of the present research was to study the effects of timing and motivational variables on a two-response DRL schedule. The primary question was whether or not timing behavior and the response-strengthening effects of reinforcement are confounded in DRL performance.

The subjects were albino rats maintained at 80% of their free-feeding body weights, and the reinforcing event was dipper presentation of a sucrose solution. A procedure was used in which two responses were required for the reinforcing event to occur. The minimum latency contingency was imposed only on the latency of the second response.

When the DRL value was varied the timing interval matched the DRL requirement more closely than in one-response DRL performance. When the subjects were pre-fed preio to the sessions to decrease the severity of deprivation, the frequency of timing behavior decreased but the accuracy of the timing intervals remained unaffected. In extinction the accuracy of timing was maintained even as the frequency of the timing behavior reached zero.

It was concluded that the strengthening effects of reinforcement presented in time are indeed confounded with the effects of reinforcement differentially presented on DRL schedules. Additionally, it was concluded that the

two-response DRL procedure allowed for these different kinds of variables to differentially affect latencies independently sensitive to them.

BIBLIOGRAPHY

Amsel, A. The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 1958, 55 102-119.

Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. Journal of Experimental Psychology, 1956. 52. 145-161.

Azrin, N. H. and Holz, W. C. Punishment. In W. K. Honig (Ed.), Operant Behavior: Areas of research and application. New York: Appleton-Century-Crofts, 1966, Pp. 380-447.

Beer, B. and Trumble, G. Timing behavior as a function of amount of reinforcement. Psychonomic Science, 1965, 2, 71-72.

Catania, A. C. (Ed.) Contemporary research in operant behavior. Glenview, Ill: Scott, Foresman, 1968.

Catania, A. C. and Reynolds, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, (3, Pt. 2).

Conrad, D. G., Sidman, M., and Herrnstein, R. J. The effects of deprivation upon temporally spaced responding. Journal of the Experimental Analysis of Behavior, 1958, 1, 59-65.

Dinsmoor, J. A. The effect of hunger on discriminated responding. Journal of Abnormal and Social Psychology, 1952, 47, 67-72.

Elsmore, T. F. Independence of postreinforcement pause length and running rate on fixed-interval pacing reinforcement schedules. Psychonomic Science, 1971, 23, 371-372.

Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. Journal of Experimental Psychology, 1941, 29, 390-400.

Farmer, J. and Schoenfeld, W. N. Inter-reinforcement times for the bar-pressing response of white rats on two DRL schedules. Journal of the Experimental Analysis of Behavior, 1964, 7, 119-122.

Ferster, C. B. and Appel, J. B. Punishment of S^{Δ} responding in matching to sample by time out from positive reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 45-56.

Ferster, C. B. and Skinner, B. F. Schedules of Reinforcement. New York: Appleton-Century-Crofts, 1957.

Finocchio, D. Changes in temporally-spaced responding as a measure of conditioned emotional behavior. Paper read at Eastern Psychological Association meetings, New York, 1963. Cited by B. Migler and J. V. Brady, Timing behavior and conditioned fear. Journal of the Experimental Analysis of Behavior, 1962, 5, 463-466.

Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5 (4, Pt. 2).

Keller, F. S. and Schoenfeld, W. N. Principles of Psychology. New York: Appleton-Century-Crofts, 1950.

Mechner, F. and Guevrekian, L. Effects of deprivation upon counting and timing in rats. Journal of the Experimental Analysis of Behavior, 1962, 5, 463-466.

Migler, B. and Brady, J. V. Timing behavior and conditioned fear. Journal of the Experimental Analysis of Behavior, 1964, 7, 247-251.

Reynolds, G. S. Accurate and rapid reconditioning of spaced responding. Journal of the Experimental Analysis of Behavior, 1964, 7, 273-275. (a)

Reynolds, G. S. Temporally spaced responding by pigeons: Development and effects of deprivation and extinction. Journal of the Experimental Analysis of Behavior, 1964, 7, 415-421. (b)

Sidman, M. Time discrimination and behavioral interaction in a free operant situation. Journal of Comparative and Physiological Psychology, 1956, 49, 469-473.

Skinner, B. F. The behavior of organisms. New York: Appleton-Century-Crofts, 1938.

Staddon, J. E. R. Some properties of spaced responding in pigeons. Journal of the Experimental Analysis of Behavior, 1965, 8, 19-27.

Staddon, J. E. R. The effect of informative feedback on temporal tracking in the pigeon. Journal of the Experimental Analysis of Behavior, 1969, 12, 27-38.

Staddon, J. E. R. and Innis, N. K. Reinforcement omission on fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 1969, 12, 689-700.

Wilson, M. P. and Keller, F. S. On the selective reinforcement of spaced responses. Journal of Comparative and Physiological Psychology, 1953, 46, 190-193.

Zimmerman, J. and Ferster, C. B. Intermittent punishment of S^{Δ} responding in matching to sample. Journal of the Experimental Analysis of Behavior, 1963, 6, 349-356.